Downloaded from orbit.dtu.dk on: May 05, 2023

DTU Library

# Removal of perfluorinated compounds from water with activated carbon and redox treatments

**Arvaniti, O. S.; Andersen, Henrik Rasmus; Hwang, Yuhoon; Antoniou, M. G.; Gatidou, G. M.; Thomaidis, N. S.; Stasinakis, A. S.**

*Publication date:*
2013

*Document Version*
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

*Citation (APA):*
Arvaniti, O. S., Andersen, H. R., Hwang, Y., Antoniou, M. G., Gatidou, G. M., Thomaidis, N. S., & Stasinakis, A. S. (2013). *Removal of perfluorinated compounds from water with activated carbon and redox treatments*. Poster session presented at CEST 2013 - 13th International Conference on Environmental Science and Technology, Athens, Greece.

**General rights**
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Removal of Perfluorinated Compounds from water With Activated Carbon and Redox Treatments

Olga S. Arvaniti[a], Henrik R. Andersen[b], Yuhoon Hwang[b], Maria G. Antoniou[c], Georgia M. Gatidou[a], Nikolaos S. Thomaidis[d] and Athanasios S. Stasinakis[a]*

[a] Water and Air Quality Laboratory, Department of Environment, University of the Aegean, Mytilene, Greece
[b] Department of Environmental Engineering, Technical University of Denmark, Kgs Lyngby, Denmark
[c] Department of Environmental Science and Technology, Cyprus University of Technology, Lemesos, Cyprus
[d] Laboratory of Analytical Chemistry, Department of Chemistry, University of Athens, Athens, Greece
Email: arvaniti@env.aegean.gr; astas@env.aegean.gr

## INTRODUCTION

Perfluorinated Compounds (PFCs) are persistent micropollutants that have been detected in various environmental and biological matrices worldwide. Monitoring studies in Sewage Treatment Plants (STPs) have shown that these compounds are not significantly removed during conventional wastewater treatment. During the last years, scientific research has focused on practices that can reduce micropollutants' concentration in wastewater effluents. However, there is limited data about the removal of PFCs with Advanced Oxidation Processes (AOPs) and Activated Carbon (AC), while no data are available about their removal with reductive treatments.

The aim of this work was to investigate the removal of 6 PFCs (C5, C8 to C11 carboxylic acids and C8 sulfonic acid) in water by i) activated carbon (Powdered Activated Carbon; PAC, Granular Activated Carbon; GAC), ii) advanced oxidation processes such as: UV/$H_2O_2$, UV/$S_2O_8^{2-}$ and iii) reductive treatments based on nano Zero Valent Iron (nZVI).

## Sorption on Activated carbon

### *Preparation of AC*

- Both GAC and PAC type activated carbon was soaked in pure water for 24 h to remove the impurities.
- Then dried in an oven at 105 ˚C for 48 h.
- Afterwards, PAC was crushed by a mortar, screened and stored in a desiccator.

### *Experiments*

- Initially, the equilibrium time was estimated for each target compound using each type of AC.
- Additional batch sorption experiments were performed with each type of AC (see Table 1) and Freundlich constants ($K_F$) values were estimated.
- Last, the influences of solution pH and cations were investigated (see Table 1).

**Table 1.** Description of sorption experiments (all experiments in triplicate).

| Types | PFCs (mg $L^{-1}$) | pH | $Na^+$ / $Ca^{2+}$ (mM) |
|---|---|---|---|
| • Powder Activated Carbon | 0.5 | 6 | - |
| | | 7 | 1 |
| | | | 10 |
| | | | 100 |
| • Granular Activated Carbon | | 8 | - |

### *Results*

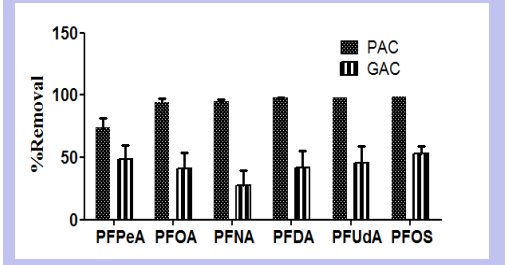


**Figure 1.** Removal of PFCs using different types of activated carbon (experimental conditions: pH=7)

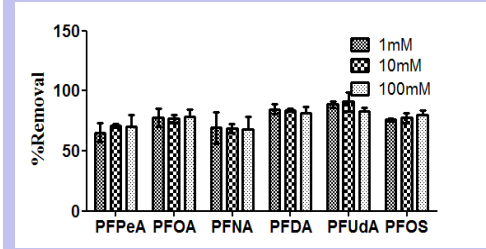


**Figure 2.** Effect of $Ca^{2+}$ on the removal of PFCs using GAC.

## Advanced Oxidation Processes

### *Experiments*

- The experiments were performed in a quasi-collimated beam apparatus (Figure 3).
- Low pressure lamps were utilized.
- Two oxidant doses were investigated for each oxidant (see Table 2).
- Samples were taken at predetermined time intervals.

**Table 2.** Experimental set up of AOPs experiments.

| Treatments | PFCs (mg $L^{-1}$) | Oxidant (mg $L^{-1}$) | Irradiation time (hours) |
|---|---|---|---|
| Control | 0.2 | - | 0 |
| UV | 0.2 | - | 12 |
| UV/ $S_2O_8^{2-}$ | 0.2 | 10 | 12 |
| UV/ $S_2O_8^{2-}$ | 0.2 | 100 | 12 |
| UV | 0.2 | - | 24 |
| UV/$H_2O_2$ | 0.2 | 20 | 24 |
| UV/$H_2O_2$ | 0.2 | 200 | 24 |

**Figure 3.** The apparatus used in this study.

## CONCLUSIONS

### Activated Carbon

- Sorption equilibrium was reached within 4 and 24 hours using PAC and GAC, respectively.
- Higher removal for all PFCs was observed for PAC than GAC (Figure 1).
- Sorption of was not affected at pH values tested (6≤pH≤8).
- No significant effect on PFCs sorption was observed when different $Ca^{2+}$ and $Na^+$ concentrations were used for both types of AC. Figure 2 depicts the results from the $Ca^{2+}$ /GAC experiments.

### Advanced Oxidation Processes

- No significant PFCs removal was observed for the experimental conditions used (data not shown).

### Nano Zero-Valent-Iron

- PFCs were only removed by nZVI modified with Mg-aminoclay.
- Higher PFCs removal was observed at pH=3 comparing to pH=5 and pH=7.
- The removal of PFCs increased with decrease of temperature (Figure 4).
- Higher removal was observed with increasing concentration of nZVI from 10 to 100 mg $L^{-1}$, while no significant increase was observed from 100 to 1000 mg $L^{-1}$ (except PFOA; Figure 5).

## Reduction with nano Zero-Valent-Iron

### *Experiments*

- Batch experiments were performed for each PFC using three types of nZVI (see Table 3).
- Samples were taken at predetermined treatment time (1, 3, 24 h).
- Additionally, the influence of nZVI concentration, solution pH and temperature were studied (see Table 3).
- With every test, samples with no $Fe^0$ were run as control.

**Table 3.** Experimental set up of nZVI experiments (all experiments in triplicate).

| Types | PFCs (mg $L^{-1}$) | nanoZVI (mg $L^{-1}$) | pH | T (˚C) |
|---|---|---|---|---|
| • Commercial nZVI | 0.2 | 10, 100, 1000 | 3 | 20 |
| | | | 3 | 55 |
| • Freshly synthesized nZVI | | | 5 | 20 |
| | | | 5 | 55 |
| • Freshly synthesized nZVI modified with Mg-aminoclay | | | 7 | 20 |
| | | | 7 | 55 |

### *Results*

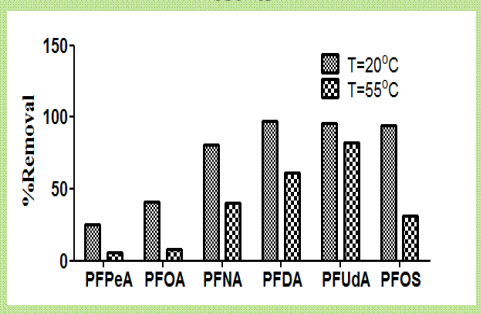


**Figure 4.** Effect of temperature on the removal of PFCs using chemically synthesized nZVI modified with Mg-aminoclay (experimental conditions: pH=3, 1000 mg $L^{-1}$ nZVI)

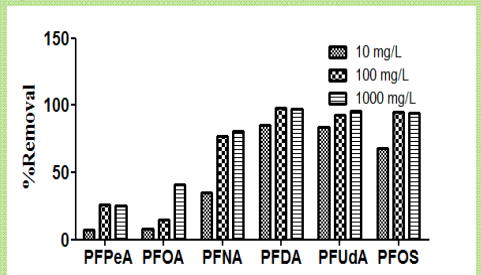


**Figure 5.** Effect of different concentrations of chemically synthesized nZVI modified with Mg-aminoclay on removal of PFCs (experimental conditions: pH=3, T=20˚C)




## ACKNOWLEDGEMENTS

This project was implemented under the Operational Program «Education and Lifelong Learning» and funded by the European Union (European Social Fund) and National Resources – HRAKLEITOS II

European Union
European Social Fund
OPERATIONAL PROGRAMME EDUCATION AND LIFELONG LEARNING
Investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS, CULTURE & SPORTS
MANAGING AUTHORITY
NSRF 2007-2013
Co-financed by Greece and the European Union

This study was presented in 13th «International Conference on Environmental Science and Technology», Athens, Greece, 5-7 September 2013 (Abstr. Code: CEST-B26).